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South Florida Water Management District
EAA Reservoir A-1 Basis of Design Report January 2006

APPENDIX 6-1

PRELIMINARY EVALUATION OF NNR AND PUMP STATIONS
TASK 5.3.3.3.2 - PRELIMINARY DATA AND INITIAL HYDRAULIC MODEL SUMMARY MEMORANDUM

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TECHNICAL MEMORANDUM

South Florida Water Management District	B&V Project 141522
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Task 5.3.3.3.2 Preliminary Data & Initial Hydraulic Model Summary Memorandum Preliminary Evaluation of NNR and Pump Stations

To: Distribution

From: Frank Means, Klint Reedy

1. OBJECTIVE

All HEC-RAS models and calculations are in NGVD29, both input and output results. To convert to NAVD88 subtract 1.4 ft from NGVD29, (NGVD29-1.4 ft=NAVD88). Conversion to NAVD88 has been completed for the text in the BODR. Calculations and model runs are in NGVD29 and text in the BODR is in NAVD88 unless otherwise stated.

The overall objective of the Hydraulic Modeling subtask is to evaluate the hydraulic characteristics of the regional conveyance system to define required modifications to existing facilities and design criteria for new facilities that will be used to transfer water into and out of the EAA Reservoir A-1. Specific objectives of this evaluation include:

- Define Hydraulic Characteristics of the Existing NNR Canal
- Identify Potential Canal Modification(s) / Improvement(s)
- Estimate Operating Ranges of New Project Facilities

2. DESIGN CONDITIONS

This evaluation focuses on modeling a series of potential operating conditions as required to develop a range of estimated flows and approximate water levels at key location within the regional canal system. Specifically, this evaluation focuses on defining available flows and estimated water levels along the NNR canal between Lake Okeechobee and the G-370 pump station. Figure 1 provides an overview of the project area showing the proximity of Lake Okeechobee, the NNR canal, and the proposed Reservoir A-1.

Figure 2 provides a profile of the NNR canal from Lake Okeechobee to the G-370 pump station. In addition to the existing facilities, Figure 2 shows the anticipated location of the new Northeast pump station that will transfer water between the NNR canal and Reservoir A-1.

Task 5.3.3.3.2 Preliminary Data & Initial Hydraulic Model Summary Memorandum
Preliminary Evaluation of NNR and Pump Stations

A wide variety of potential operating conditions were evaluated including dry weather operating conditions with Lake Okeechobee supplying 100 percent of the flows to the NNR canal, wet weather conditions with both Lake Okeechobee and runoff contributing to the flows in the canal, and dry weather conditions with Reservoir A-1 supplying flows to the north. The following sections describe the assumptions for each potential operating or design condition.

2.1 Design Condition 1: NNR Canal Flowing South with no Lateral Flows

During dry weather conditions the water supply for the NNR canal is anticipated to be either Lake Okeechobee or Reservoir A-1. Design Condition 1 evaluates a series of flows that can be conveyed in the NNR canal from Lake Okeechobee to the Northeast pump station and the G-370 pump station assuming a maximum velocity of 2.5 fps, a minimum two foot freeboard is maintained, and a maximum water level of 11.6 ft (NAVD) at the Bolles/Cross canal intersection is observed.

Figure 3 provides a schematic of the simulated dry weather flow conditions with the NNR flowing south. Table 1 summarizes the resulting flows and water surface elevations at key locations in the NNR canal.

2.2 Design Condition 2: NNR Canal Flowing South with Lateral Flows

During wet weather conditions the NNR canal is anticipated to flow south towards Reservoir A-1 and convey water from both Lake Okeechobee and lateral flows from runoff pumped from the local farm lands into the canal. Design Condition 2 evaluates a series of flows that can be conveyed south in the NNR canal assuming a maximum velocity of 2.5 fps, a minimum two foot freeboard, and a maximum water level of 11.6 ft (NAVD) at the Bolles/Cross canal intersection.

Table 2 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming a ¾-inch runoff per day pumping rate is occurring from the farm lands along with flow being discharged from Lake Okeechobee. Table 3 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming a 1 ½-inch runoff per day pumping rate is occurring from the farm lands along with flow being discharged from Lake Okeechobee. Figure 4 provides a schematic of the simulated flow conditions under wet conditions with the NNR flowing south.

2.3 Design Condition 3: NNR Canal Flowing North from Reservoir A-1

During dry weather conditions, water stored in Reservoir A-1 can be delivered north via the NNR canal to meet farming demands along the NNR canal or to supplement flows in the Bolles and Cross canals. Design Condition 3 evaluates a series of operating conditions that help define the anticipated flow rates and corresponding water levels when delivering water north from Reservoir A-1 assuming a maximum velocity of 2.5 fps and a minimum two foot freeboard is maintained. Table 4 summarizes the results of this evaluation.

2.4 Design Condition 4: Modified NNR Canal (Removal of Hump)

There is an existing high point or "hump" within the NNR canal between River Station (RS) 21 and 24, south of the Bolles/Cross canal intersection. This high point was removed in the model and flow conditions similar to Design Conditions 1 and 3 were simulated to determine the potential for capacity improvements. As with the previous design conditions, the velocity was limited to 2.5 fps and a minimum 2 foot freeboard was maintained.

Table 5 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming the removal of the hump, water flowing south, and no lateral flows. Table 6 summarizes the resulting flows and water surface elevations at key locations in the NNR canal assuming the removal of the hump, water flowing north, and no lateral flows.

2.5 Design Condition 5: NNR Canal Capacity without Velocity Limits

Design Conditions 1 through 4 evaluate the hydraulic characteristics of the NNR canal while limiting the velocity to no more than 2.5 fps and maintaining a minimum 2 foot freeboard. Design Condition 5 performs a brief evaluation of the NNR capacity to convey water south maintaining the desired 2 foot freeboard criteria, but allowing the velocity to exceed 2.5 fps. Table 7 summarizes the results of this evaluation.

3. MODEL CONFIGURATION

To be provided as part of Task 5.3.3.6.2 Hydraulic Model Technical Summary Memorandum.

4. MODEL CALIBRATION, VERIFICATION AND RELIABILITY

To be provided as part of Task 5.3.3.6.2 Hydraulic Model Technical Summary Memorandum.

5. RESULTS

The initial results are presented in the following seven tables.

6. SUMMARY AND CONCLUSIONS

To be provided as part of Task 5.3.3.6.2 Hydraulic Model Technical Summary Memorandum.

7. REFERENCES

Jacobs/MWH, *Bolles & Cross Canals Preliminary-Hydraulics Report.* June 15, 2004.

Brockway, C. *Canal Alternatives Technical Memorandum (Draft).* June 2005.

TABLES

Table 1 NNR Flowing South with no Lateral Flows

(All Elevations are in NAVD)							
Run #	G-370 PS		Northeast PS		B/C Flow (cfs)	Bolles/ Cross WSEL (ft)	Lateral Flows (cfs)
	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)			
1	2350 (VC)(1)	8.6 (S)	525 (S) (EC)	9.9 (C)	2875 (C) (EC)	11.6 (C) (EC)	0 (S)
2	1850 (S)(2)	8.6 (S)	1260 (S)(VC)	9.4 (C)	3110 (C) (VC)	11.5 (C)	0 (S)
3	925 (S)(3)	8.6 (S)	2025 (S)(VC)	8.8 (C)	2950 (C) (VC)	10.8 (C)	0 (S)
(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable (EC) – Elevation controlled variable (FC) – Freeboard controlled variable.							
(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each. (2) Two 925 cfs pumps. (3) One 925 cfs pump.							

Run 1: Setting the WSEL at 8.6 ft (NAVD) resulted in a calculated maximum allowable flow rate of 2350 cfs at G-370 to limit the velocity to 2.5 fps between G-370 and the Northeast pump station. The flow rate of 2350 cfs resulted in a calculated WSEL of 9.9 ft (NAVD) at the Northeast pump station. Per trial and error, a set flow rate of 525 cfs at the Northeast pump station resulted in a total supply flow from Bolles/Cross of 2875 cfs, which resulted in the maximum allowable WSEL of 11.6 ft (NAVD) at the Bolles/Cross intersection. Three pumps are in operation, however, due to the maximum allowable WSEL of 11.6 ft (NAVD) being reached, the pumps would need to be throttled back to 785 cfs each.

Run 2: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to two pumps (2 x 925 cfs) results in a calculated WSEL of 9.4 ft (NAVD) at the Northeast pump station. This is lower than Run #1 (9.9 ft (NAVD)) water level, provided a greater differential head, and allowed for increased flows in the NNR canal.

Run 3: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to one pump (1 x 925 cfs) resulted in a calculated WSEL of 8.8 ft (NAVD) at the Northeast pump station. This is lower than Run #2 water level, resulted in slightly less available cross sectional area and consequently velocities were higher, and the allowable maximum flow rate at 2.5 fps was slightly less than Run #2. For example, the Run #2 total flow equaled 3110 cfs and Run #3 total flow equaled 2950 cfs. As illustrated in the results table, when the flow rate capacity of G-370 is reduced an increase in flow rate capacity can occur at the Northeast pump station.

Table 2 NNR Flowing South with Lateral Flows Due to ¾-inch Rain

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	B/C Flow (cfs)	Bolles/ Cross WSEL (ft)	Lateral Flows (cfs)
1	2350 (VC) (1)	8.6 (S)	1575 (S)(VC)	9.8 (C)	2164 (C) (VC)	11.4 (C)	1761 (S)
2	1850 (S)(2)	8.6 (S)	1961 (S)(VC)	9.4 (C)	2050 (C) (VC)	10.9 (C)	1761 (S)
3	925 (S)(3)	8.6 (S)	2736 (S)(VC)	8.8 (C)	1900 (C) (VC)	10.3 (C)	1761 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.
(2) Two 925 cfs pumps.
(3) One 925 cfs pump.

Run 1: Setting the WSEL at 8.6 ft (NAVD) resulted in a calculated maximum allowable flow rate of 2350 cfs at G-370 to limit the velocity to 2.5 fps between G-370 and the Northeast pump station. The flow rate of 2350 cfs (considering the 745 cfs lateral flow shown on Figure 2.2-1) resulted in a calculated WSEL of 9.8 ft (NAVD) at the Northeast pump station. Per trial and error, a set flow rate of 1575 cfs at the Northeast pump station resulted in a total supply flow from Bolles/Cross of 2164 cfs (considering the 1016 cfs lateral flow shown on Figure 4), which resulted in the calculated WSEL of 11.4 ft (NAVD) at the Bolles/Cross intersection.

Run 2: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to two pumps (2 x 925 cfs) results in a calculated WSEL of 9.4 ft (NAVD) at the Northeast pump station. This is lower than Run #1 water level, provided a greater differential head, and allowed for increased flows in the NNR canal. Additionally, because lateral flows introduced along the canal and are not conveyed the entire distance from the Bolles/Cross intersection, the maximum potential flow at the Northeast pump station is approximately 700 cfs greater than the dry season operating condition show in Table 1, Run #2.

Run 3: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to one pump resulted in a calculated WSEL of 8.8 ft (NAVD) at the Northeast pump station. This is lower than Run #2 water level, resulted in slightly less available cross sectional area and consequently velocities were higher, and the allowable maximum flow at 2.5 fps was slightly less than Run #2. For example, Run #2 total flow equaled 3811 cfs (2050+1761) and Run #3 total flow equaled 3661 cfs (1900+1761).

Table 3 NNR Flowing South with Lateral Flows Due to 1 ½ -inch Rain

(All Elevations are in NAVD)

Run #	G-370 PS Flow (cfs)	G-370 PS WSEL (ft)	Northeast PS Flow (cfs)	Northeast PS WSEL (ft)	B/C Flow (cfs)	Bolles/ Cross WSEL (ft)	Lateral Flows (cfs)
1	2350 (VC) (1)	8.6 (S)	2272 (S)(VC)	9.7 (C)	1100 (C) (VC)	10.8 (C)	3522 (S)
2	1850 (S)(2)	8.6 (S)	2682 (S)(VC)	9.3 (C)	1010 (C) (VC)	10.4 (C)	3522 (S)
3	1490 (S)(3)	8.6 (S)	2971 (S)(VC)	9.0 (C)	940 (C) (VC)	10.1 (C)	3522 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.
(2) Two 925 cfs pumps.
(3) Flow equal to lateral inflow. Requires throttling two pumps to 745 cfs each.

Run 1: Setting the WSEL at 8.6 ft (NAVD) resulted in a calculated maximum allowable flow rate of 2350 cfs at G-370 to limit the velocity to 2.5 fps between G-370 and the Northeast pump station. The flow rate of 2350 cfs (considering the 1490 cfs lateral flow which is double that shown on Figure 4) resulted in a calculated WSEL of 9.7 ft (NAVD) at the Northeast pump station. Per trial and error, a set flow rate of 2272 cfs at the Northeast pump station resulted in a total supply flow from Bolles/Cross of 1100 cfs (considering the 2032 cfs lateral flow), which resulted in the calculated WSEL of 10.8 ft (NAVD) at the Bolles/Cross intersection.

Run 2: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to two pumps (2 x 925 cfs) results in a calculated WSEL of 9.3 ft (NAVD) at the Northeast pump station. This is lower than Run #1 water level, provided a greater differential head, and allowed for increased flows in the NNR canal. Additionally, because lateral flows introduced along the canal and are not conveyed the entire distance from the Bolles/Cross intersection, the maximum potential flow at the Northeast pump station is approximately 1400 cfs greater than the dry season operating condition show in Table 1, Run #2.

Run 3: Setting the WSEL at 8.6 ft (NAVD) and setting the flow rate at G-370 equal to one pump resulted in a calculated WSEL of 9.0 ft (NAVD) at the Northeast pump station. This is lower than Run #2 water level, resulted in slightly less available cross sectional area and consequently velocities were higher, and the allowable maximum flow at 2.5 fps was slightly less than Run #2. For example, Run #2 total flow equaled 4532 cfs (1010+3522) and Run #3 total flow equaled 4462 cfs (940+3522).

Table 4 NNR Flowing North with no Lateral Flows

(All Elevations are in NAVD)							
Run #	G-370 PS		Northeast PS		A-1	Bolles/ Cross	Lateral
	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)	Flows (cfs)
1	0 (S) (C)	10.9 (C)	1225 (S) (FC)	10.9 (C)	1225 (S)	10.6 (S)	0 (S)
2	0 (S) (C)	11.1 (C)	2510 (S) (FC)	11.1 (C)	2510 (S)	9.6 (S)	0 (S)
3	0 (S) (C)	10.8 (C)	2890 (S) (FC)	10.8 (C)	2890 (S)	8.6 (S)	0 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

Run 1: Setting the WSEL at 10.6 ft (NAVD) at the Bolles/Cross intersection results in a calculated maximum allowable flow rate of 1225 cfs before encroaching upon the minimum 2 foot freeboard.

Run 2: Lowering the WSEL to 9.6 ft (NAVD) at the Bolles/Cross intersection results in greater flow capacity than Run #1 because the lower downstream water level provides for greater differential head and the lower water level provides for more room before encroaching on the 2 foot freeboard.

Run 3: Lowering the WSEL at the Bolles/Cross intersection to 8.6 ft (NAVD) results in even greater flow capacity. At this elevation, the capacity is limited by the maximum velocity requirements of 2.5 fps, instead of encroaching upon the minimum allowable freeboard.

Table 5 NNR Flowing South without Hump no Lateral Flows

(All Elevations are in NAVD)

Run #	G-370 PS		Northeast PS		B/C Flow (cfs)	B/C WSEL (ft)	Lateral Flows (cfs)
	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)			
1	2350 (VC) (1)	8.6 (S)	720 (S) (EC)	9.9 (C)	3070 (C) (EC)	11.6 (C) (EC)	0 (S)
2	2170 (VC)	7.6 (S)	830 (S)(VC)	8.9 (C)	3000 (C)(VC)	10.9 (C)(VC)	0 (S)
3	1985 (VC)	6.6 (S)	800 (S)(VC)	8.0 (C)	2785 (C)(VC)	10.0 (C)(VC)	0 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

(1) Existing pump capacity is 925 cfs each, 2,350 cfs flow rate requires throttling 3 pumps to 785 cfs each.

Run 1: Run #1 from Table 5 simulates the same condition evaluated under Run #1 from Table 1 with the high point (hump) removed. Comparing the two results, an additional 195 cfs (720 cfs – 525 cfs) can be transferred to the Northeast pump station while maintaining the maximum desirable WSEL of 11.6 ft (NAVD) at the Bolles/Cross intersection. Removing the hump results in approximately 7 percent increase in flow (3070 cfs versus 2875 cfs) at Bolles/Cross for this operating condition.

Run 2: Run #2 from Table 5 simulates the same condition as Run #1 from Table 5, with a lower set water elevation at the G-370 pump station. Comparing the results from Run #1 and Run #2, lowering the water level resulted in slightly less available cross sectional area and consequently velocities were higher, and the allowable maximum flow to the G-370 pump station was reduced from 2350 cfs to 2170 cfs. This resulted in a reduced total supply flow of 3,000 cfs.

Run 3: Run #3 from Table 5 simulates the same condition as Run #1 and Run #2 from Table 5, with an even lower set water elevation at the G-370 pump station. Comparing the results, the available capacity was further reduced.

Table 6 NNR Flowing North without Hump no Lateral Flows

(All Elevations are in NAVD)							
Run #	**G-370 PS**		**Northeast PS**		**A-1**	**B/C**	**Lateral**
	Flow (cfs)	**WSEL (ft)**	**Flow (cfs)**	**WSEL (ft)**	**Flow (cfs)**	**WSEL (ft)**	**Flows (cfs)**
1	0 (S) (C)	10.9 (C)	1310 (S) (FC)	10.9 (C)	1310 (S)	10.6 (S)	0 (S)
2	0 (S) (C)	11.1 (C)	2700 (S) (FC)	11.1 (C)	2700 (S)	9.6 (S)	0 (S)
3	0 (S) (C)	10.9 (C)	3200 (S) (VC)	10.9 (C)	3200 (S)	8.6 (S)	0 (S)
(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable (EC) – Elevation controlled variable (FC) – Freeboard controlled variable.							

Run 1: Run #1 from Table 6 simulates the same condition evaluated under Run #1 from Table 4 with the high point (hump) removed. Comparing the two results, an additional 85 cfs (1310 cfs – 1225 cfs) can be transferred north from Reservoir A-1 while maintaining the minimum required freeboard of 2 ft. Under this operating condition, removing the hump in the canal yields a 7 percent increase in the capacity.

Run 2: Run #2 from Table 6 simulates the same condition as evaluated under Run #2 from Table 4 with the high point (hump) removed. Comparing the two results, an additional 190 cfs (2700 cfs – 2510 cfs) can be transferred north from Reservoir A-1 while maintaining the minimum required freeboard of 2 ft. Under this operating condition, removing the hump in the canal yields an 8 percent increase in the capacity.

Run 3: Run #3 from Table 6 simulates the same condition as evaluated under Run #3 from Table 4 with the high point (hump) removed. Comparing the two results, an additional 310 cfs (3200 cfs – 2890 cfs) can be transferred north from Reservoir A-1 while maintaining the velocity limit of 2.5 fps. Under this operating condition, removing the hump in the canal yields an 11 percent increase in the capacity.

Table 7 NNR Flowing South without Velocity Restrictions

(All Elevations are in NAVD)

Run #	G-370 PS		Northeast PS		B/C Flow (cfs)	B/C WSEL (ft)	Lateral Flows (cfs)
	Flow (cfs)	WSEL (ft)	Flow (cfs)	WSEL (ft)			
1	1850 (S)	8.6 (S)	1375 (C) (EC)	9.4 (C)	3225 (C) (EC)	11.6 (C) (EC)	0 (S)
2 *	1850 (S)	6.6 (S)	4200 (S) (EC)	7.5 (C)	3150 (C) (EC	11.6 (C) (EC)	2900 (S)
3 *	2775 (S)	8.6 (S)	1900 (S) (EC)	10.0 (C)	1775 (C) (EC	11.6 (C) (EC)	2900 (S)

(S) – Set variable (C) – Calculated variable (VC) – Velocity controlled variable
(EC) – Elevation controlled variable (FC) – Freeboard controlled variable.

* Simulation assumes no hump and no maximum velocity.

Run 1: Run #1 from Table 7 simulates the same condition evaluated under Run #2 from Table 1 only the velocity limits were not applied. Therefore, instead of velocity limiting the available capacity, the target WSEL of 11.6 ft (NAVD) at the Bolles/Cross canal intersection was the limiting operating criteria. Comparing the two results, an additional 115 cfs (3225 cfs – 3110 cfs) equal to approximately 4 percent can be transferred south.

Run 2: Run #2 from Table 7 simulates the NNR canal flowing south during a wet period similar to the operating conditions summarized in Tables 2 and 3. Run #2 from Table 7 shows that a total capacity of 6050 cfs (1850 cfs + 4200 cfs) can be accomplished if the hump is removed and the velocity limits are not applied. This is estimated to be approximately 25% greater than flow conditions shown in Tables 2 and 3 for similar operating conditions.

Run 3: Run #3 from Table 7 simulates the NNR canal flowing south during a wet period similar to Run #2 from Table 7 except the maximum pumping capacity at the G-370 pump station is simulated. Under this condition, the high flow rate between the Northeast pump station and the G-370 pump station results in high energy losses and consequently the available flow rate to the Northeast pump station is significantly reduced. Therefore, even when removing the hump and not applying the velocity limits to the analysis, the total capacity of 4676 cfs is very similar to the total capacity available under Run #1 Table 3, which included the hump and did not exceed the 2.5 fps velocity limit.

FIGURES

Figure 1 Reservoir and Canal Location Map

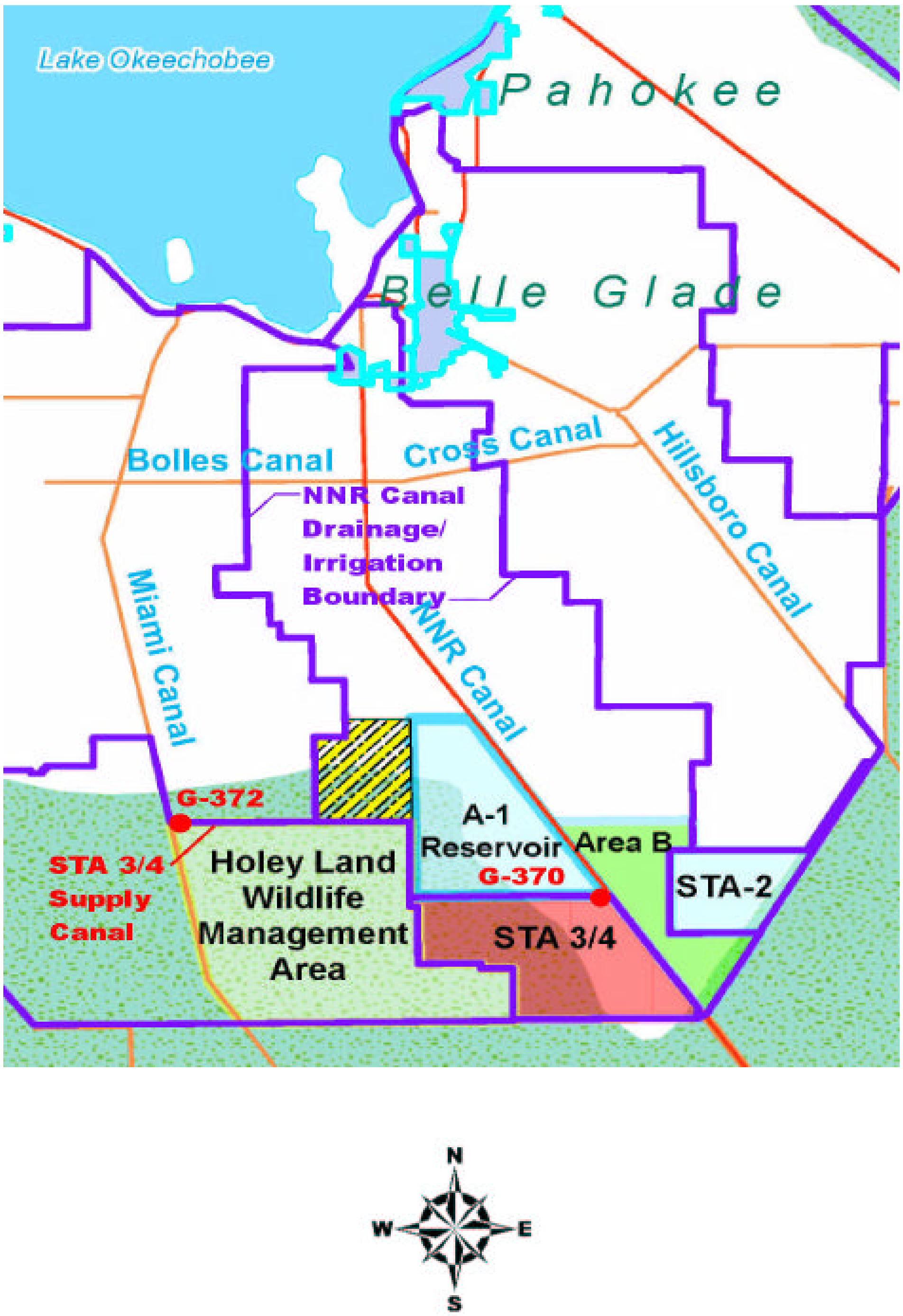
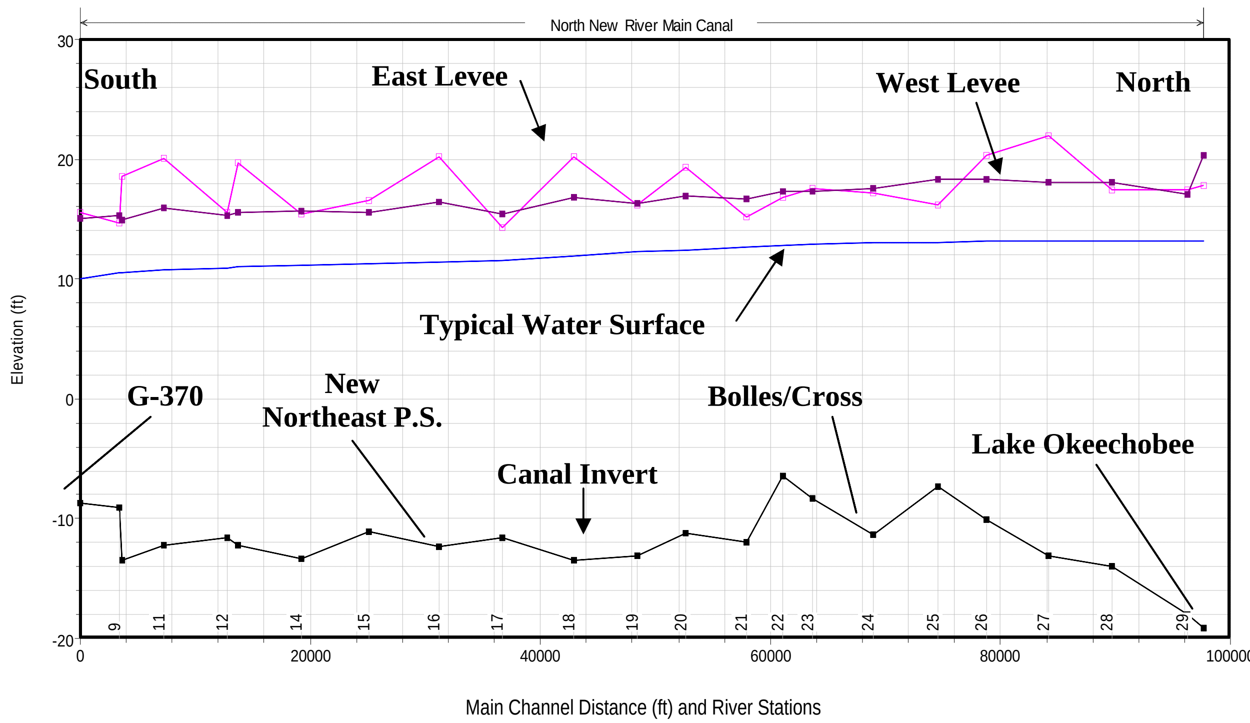


Figure 2 NNR Canal Profile



Elevation (ft) is NGVD 29
NGVD 29 – 1.4 ft. = NAVD88

Figure 3 NNR Flowing South – Dry Conditions

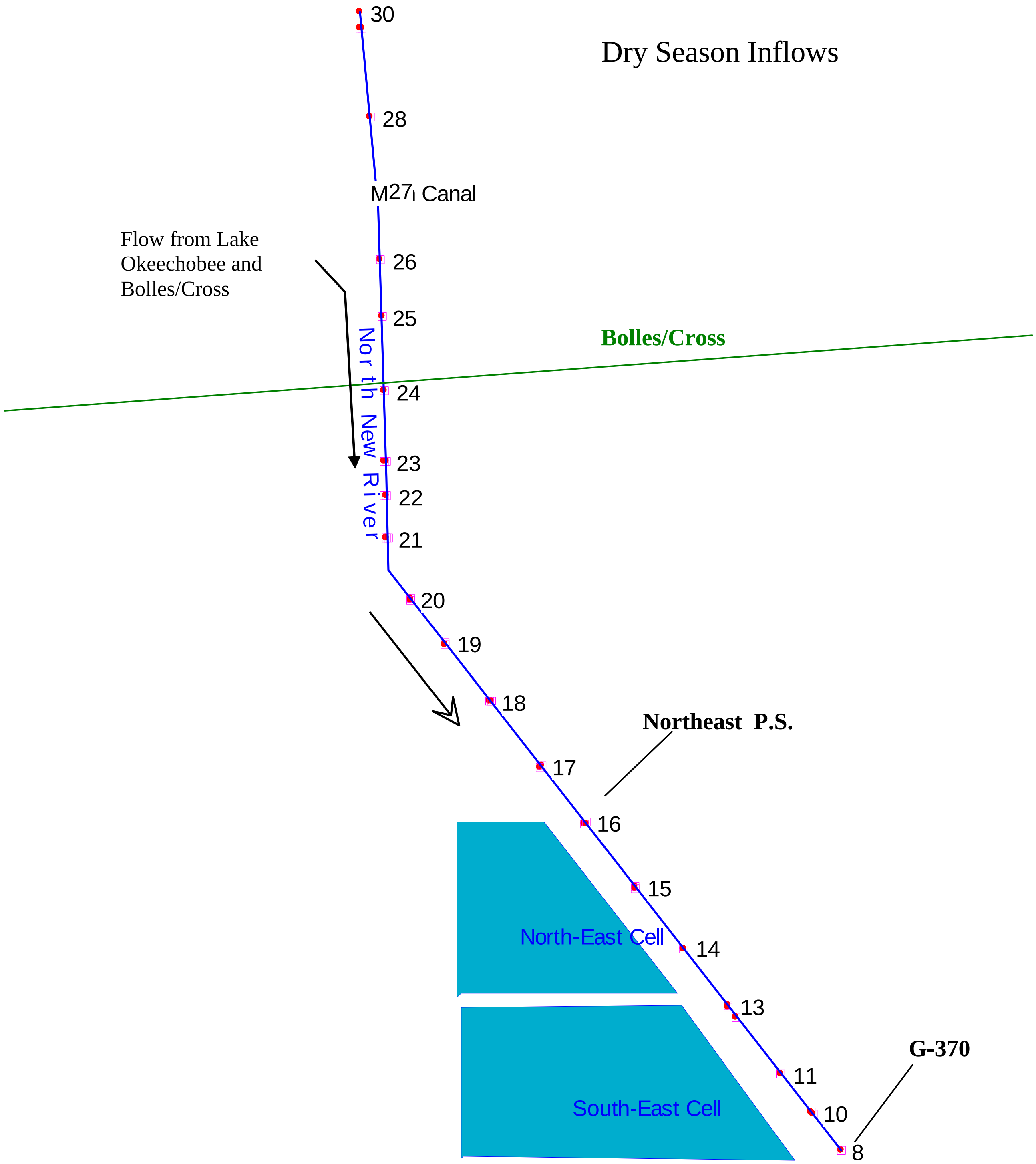


Figure 4 NNR Flowing South – Wet Conditions (3/4-inch Wet Season)